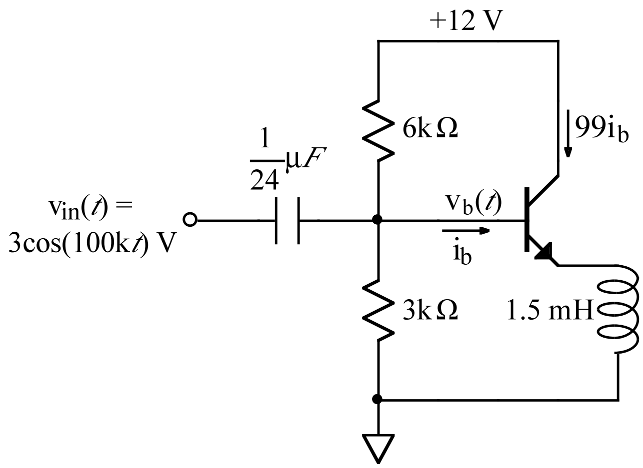
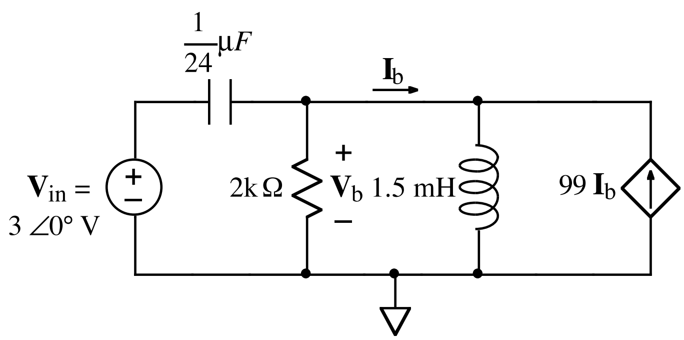
HOMEWORK #17 prob 5 solution

Ex:



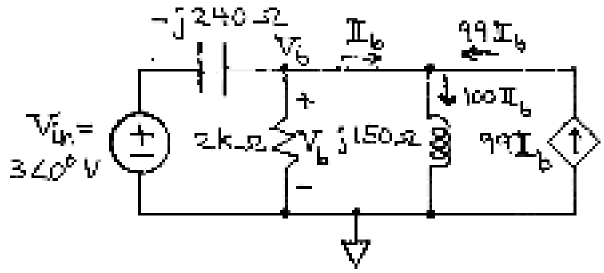


The above circuit diagrams show an emitter-follower amplifier and its high-frequency equivalent circuit. Find $v_b(t)$.

soln: The bottom diagram uses a mixed notation in that the C and L values are shown instead of z_C and z_L. We first compute z_C and z_L using $\omega = 100k$ from the top circuit.

$$z_C = \frac{1}{j\omega C} = \frac{-j}{\omega C} = \frac{-j}{100k \cdot \frac{1}{24}\mu}\,\Omega = -j\,240\,\Omega$$

$Z_L = j\omega L = j\,100k \cdot 1.5\,mH = j150\,\Omega$



A straightforward solution approach is to use the node-voltage method with V_b on the top rail.

$$\frac{V_b - V_{in}}{-j240\,\Omega} + \frac{V_b}{2k\Omega} + \frac{V_b}{j150\,\Omega}\cdot\frac{1}{100} = 0\,A$$

or $$V_b\left(\frac{1}{-j240\,\Omega} + \frac{1}{2k\Omega} + \frac{1}{j15k\Omega}\right) = \frac{V_{in}}{-j240\,\Omega}$$

or $$V_b = \frac{V_{in}}{-j240\,\Omega}\cdot -j240\,\Omega \,\|\, 2k\Omega \,\|\, j15k\Omega$$

or $$V_b = V_{in}\cdot 1 \,\Big\|\, \frac{2k}{-j240} \,\Big\|\, \frac{-15k}{240}$$

Now $$1 \,\Big\|\, \frac{-15k}{240} = \frac{1\left(\frac{-15k}{240}\right)}{1 + \frac{-1.5k}{240}} = \frac{-15k}{240 - 15k}$$

$$" = \frac{15k}{14.76k} = \frac{15}{14.76}$$

$$V_b = V_{in} \cdot \frac{15}{14.76} \,\Big\|\, \frac{2k}{-j240}$$

$$= V_{in} \cdot \frac{15}{14.76} \,\Big\|\, j\frac{25}{3}$$

$$= 3\angle 0^\circ\,V \cdot \frac{\frac{15}{14.76} \cdot j\frac{25}{3}}{\frac{15}{14.76} + j\frac{25}{3}}$$

$$= 3\angle 0^\circ\,V \cdot \frac{j\,15(25)}{3(15) + j\,25(14.76)}$$

$$= 3\angle 0^\circ\,V \cdot \frac{j\,3(25)}{3 \cdot 3 + j\,5(14.76)}$$

$$= 3\angle 0^\circ\,V \cdot \frac{j\,75}{9 + j73.8}$$

$$= \frac{225\angle 90^\circ\,V}{\sqrt{9^2 + 73.8^2}\,\angle \tan^{-1}\frac{73.8}{9}}$$

$$= \frac{225\angle 90^\circ\,V}{74.3\angle 83.0^\circ}$$

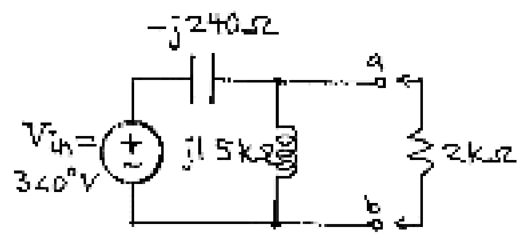
$$\approx 3.02\angle\, 90^\circ - 83.0^\circ\ V$$

$$V_b \doteq 3\angle 7^\circ \quad V$$

$$\therefore v_b(t) \doteq 3\cos(100kt + 7^\circ)\ V$$

An alternate approach begins with the observation that the L and the dependent source may be replaced by $j\omega L \cdot 100$. This concept is called "impedance multiplication".

Then we remove the $2k\Omega$ resistor and find the Thevenin equivalent of the circuit with respect to the terminals where the $2k\Omega$ resistor is attached.



$$V_{Th} = V_{a,b \text{ no load}}$$

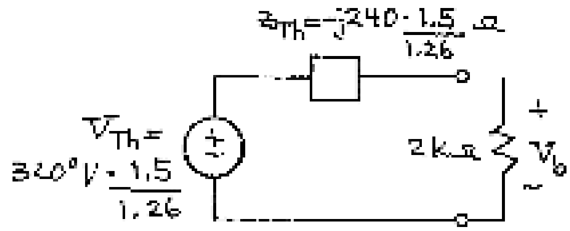
$$= V_{in} \cdot \frac{j15k\Omega}{j15k\Omega - j240\,\Omega}$$

$$V_{Th} = 3\angle 0°V \cdot \frac{15}{14.76}$$

Z_{Th} = Z seen looking into a,b with V_{in} off (= wire)

$$Z_{Th} = -j240 \| j15k\ \Omega$$

$$Z_{Th} = \frac{240(15k)}{j(15k - 240)}\,\Omega = -j240 \cdot \frac{15}{14.76}\ \Omega$$



$$V_b = V_{Th} \cdot \frac{2k\Omega}{2k\Omega + Z_{Th}}$$

$$= 3\angle 0°\ V \cdot \frac{15}{14.76} \cdot \frac{2k\Omega}{2k\Omega - j240 \cdot \frac{15}{14.76}\ \Omega}$$

$$= 3\angle 0°\ V \cdot \frac{15\,(2k\Omega)}{14.76\,(2k\Omega) - j\,240\,(15)\,\Omega}$$

$$= 3\angle 0°\ V \cdot \frac{30k}{29.52k - j\,3.6k}$$

$$= 3\angle 0°\ V \cdot \frac{30}{29.52 - j\,3.6}$$

$$= 3\angle 0°\ V \ \frac{1}{0.984 - j0.12}$$

$$= \frac{3\angle 0°\ V}{0.99\angle -6.95°}$$

$$V_b \doteq 3\angle 7°\ V$$

$$\therefore\ v_b(t) = 3\cos(100kt + 7°)\ V$$